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A Study of High Frequency Nonlinear Combustion Instability in Baffled Annular Liquid Propellant Rocket Motors

The problem:

In the design and development of liquid propellant rocket motors, certain gas dynamic disturbances that frequently occur can cause instability in the combustion processes. If these initial pressure disturbances are of the proper frequency, reinforcement by the combustion processes can take place, and engine shutdown or even destruction may occur.

The solution:

A new computer program contains a mathematical model which provides a relationship between the engine gas dynamics and combustion processes. Mathematically simulated bomb-like explosions are used to initiate the gas disturbances. Design methods for damping these disturbances and for providing stable combustion processes can then be studied.

How it's done:

Experiments were performed using a numerical model for several of the processes occurring in the combustion chamber of an annular rocket motor. The model leads to a numerical simulation of the complete nonlinear gas dynamic flow field in an annular motor. The fundamental assumption is that the combustion process is controlled by an evaporation mechanism. However, the model can be modified to include chemical kinetic energy release models.

The model considers three regimes of gas dynamic flow; the subsonic combustion zone adjacent to the injector face, the transonic region in the converging-diverging nozzle, and the supersonic outflow region in the diverging section of the nozzle. Up to six baffled compartments are allowed in the combustion chamber, each of which may have a length ranging up to and in-

cluding the combustor length. The compartment boundaries may be specified at arbitrary angular positions around the circumference of the chamber.

Interacting with the gas dynamic flow in the subsonic combustor is a droplet field approximating a dilute spray. The drops experience aerodynamic forces through a difference in velocities between gas and droplet. The force field resulting from the velocity field is time dependent; therefore, motion of the droplet field is also time dependent. Droplets of prescribed radius are injected into the chamber and are allowed to evaporate and accelerate in the dynamic gas field. The droplet field equations are then solved for in a Lagrangian frame.

The solution of the droplet evaporation and dynamic equations provides the source term for the gas dynamic equations. The reinforcement of an initial pressure disturbance present in the combustor is then possible. Dependence on the phase of the wave with respect to the time dependent combustion field partially determines success or failure of the amplification process. The energy supplied to the wave versus energy outflow by advection is another important criterion.

The method developed in this research effort for nonlinear rocket modeling in two space dimensions may prove useful for analyzing the stability limits in rocket motors yet to be designed and built.

Notes:

1. This program is written in FORTRAN V for use on the UNIVAC 1108 computer, and can be converted for use on any computer that has a FORTRAN IV or FORTRAN V compiler.

(continued overleaf)

2. Requests for further information may be directed
to:

COSMIC
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Reference: B71-10532

Patent status:

No patent action is contemplated by NASA.

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